

**EVALUATION OF STORAGE TECHNIQUES TO IMPROVE THE SEED LONGEVITY AND SHELF LIFE
OF HORSEGRAM.**

ABSTRACT

Horsegram (*Macrotyloma uniflorum*) is a robust, drought-resistant crop that is valued for its high protein content and is a significant food source in many parts of the world. Horsegram seeds must be stored properly to preserve their freshness, nutritional value, and viability for future planting. In this article an investigation was carried out to evaluate the suitable seed treatment and packaging materials for maintaining the shelf life of horsegram seeds during storage. The laboratory experiment was carried out at Department of Seed Science and Technology, Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, India. The graded seeds of horsegram were treated with different botanicals (Neem seed kernel powder @ 5g/kg & Pungam leaf powder @ 5g/kg), herbal oil (Neem oil @ 5ml/kg) and chemical (Malathion @ 5g/kg) and packed in cloth and super grain bags which was kept under ambient condition. The physical, physiological and biochemical parameters were assessed from the stored seed samples. Horsegram seeds dusted with malathion at 5 g/kg and then packed in a super grain bag have better germination (94%), root length (18.33 cm), shoot length (9.10 cm), DMP (0.165 g seedlings-10), vigour index I and II (2551 and 16.2), and also biochemical parameters like the lowest electrical conductivity (0.121 dSm⁻¹), highest enzyme activity like dehydrogenase (0.521) and catalase (0.213 units g⁻¹) and protein level (19.21%) was also high in malathion (5 g/kg) treated seeds packed in a super grain bag after storage for 8 months.

KEYWORDS: Horsegram, seed storage, treatments, packaging materials, germination

Introduction

Horsegram (*Macrotyloma uniflorum*) belongs to family Fabaceae. It is a potential grain legume having excellent nutritional and remedial properties with better climate resilience to adapt harsh environmental conditions. It is one of the most important unexploited food legume being grown in almost all over the world including temperate and subtropical regions. In India, horsegram is cultivated in 4.61 lakh ha with productivity of 1000 kg/ha in Telangana followed by Uttarkhand with a productivity of 923 kg/ha. In Tamil Nadu, horsegram is cultivated in 0.8 lakh ha with productivity of 691 kg/ha (Indiastat, 2019). Seed is an important input in agriculture that impacts not only production but also productivity, therefore maintaining seed quality and vigour during storage is crucial. Storage is a basic technique in the control of the physiological quality of the seed, and it is a way for preserving the viability of the seeds and maintaining their vigour during the time between planting and harvesting. Seed storage is necessary to preserve high seed quality for future use. Packing of seeds is done to prevent the absorption of water from atmosphere after drying and also minimize the contamination of seeds due to insects and diseases. Seeds are stored in moisture proof containers removed the dampness, deterioration, microbes and maintain the seed longevity in brinjal seeds (Kumar *et al.* 2008). Sunflower seeds in kraft paper packing were stored more effectively and maintained physiological integrity in a cold chamber (Abreu *et al.* 2013). Seed treatments play a significant role in improving the establishment of healthy crops as well as reduce losses of seed during storage. Soyabean seeds treated with Imidacloprid and Tiocarbe + Carbendazim and Tiram maintained the physiological quality of seeds stored for a period of two months (Ferreira *et al.* 2016). Keeping this background, present study was carried out to identify the suitable seed treatments and packing material to maintain the shelf life of horse gram seeds.

Materials and Methods

The graded seeds of horsegram were treated with different botanicals, herbal oil and chemical as per the treatment scheduled viz, T₀ -Control, T₁-Malathion @ 5g/kg, T₂-Pungam leaf powder @ 5g/kg, T₃-Neem oil @ 5ml/kg, T₄-Neem seed kernel powder @ 5g/kg. The treated seeds were allowed to dry back to their original moisture content, packed in cloth (C₁) and super grain bags (C₂) which was kept under ambient condition for about eight months by following FCRD. The seed samples were drawn bimonthly interval and subjected to quality analysis viz., seed physical character Seed Moisture Content

(%) and physiological characters such as germination (%), root length (cm), shoot length (cm), dry matter production (g/10 seedlings) and vigour index (Abdul- Baki and Anderson, 1973). Seed moisture content was calculated and the mean expressed as percentage adopting the following formula.

$$M2 - M3$$

$$\text{Moisture content (\%)} = \frac{\text{-----}}{\text{-----}} \times 100$$

$$M2 - M1$$

Where,

M1=Weight of the empty container with its cover, M2= Weight of the container with its cover and seeds before drying.

M3= Weight of the container with its cover and seeds after drying.

The germination test was carried out as per the procedure prescribed by ISTA (2013). After nine days, the normal seedlings produced were counted and expressed as percentage. The vigour index I and vigour index II were calculated using following formula.

$$\text{Vigour index I} = \text{Germination (\%)} \times \text{Total seedling length (cm)}.$$

$$\text{Vigour index II} = \text{Germination (\%)} \times \text{Dry matter production (g/10 seedlings)}.$$

Further, the seed biochemical parameters like Dehydrogenase (OD value) activity (Kittock and Law, 1968) , Electrical conductivity (dSm^{-1}) (Presley, 1958), Protein content (%) (Ali-Khan and Youngs, 1973), Catalase activity (Units g^{-1}) (Luck, 1974) were also estimated. From the optical density values, the protein content was calculated using the following formula.

$$\text{Protein content (\%)} = 3.78 + (61.6 \times \text{Optical Density value})$$

Catalase activity was expressed as units/g tissue using the following formula.

$$\text{Catalase activity} = \frac{17 \times 10 \times 20 \times 1000}{\Delta t \times X \times Y} \times 100$$

Where

Δt – Time required to decrease the absorbance; X – Volume of enzyme extract

Y – Volume of buffer solution

Seed infestation was indicated through presence of holes in each treatment counted and expressed in percentage.

$$\text{Per cent Infestation (\%)} = \frac{\text{No. of damaged seeds}}{\text{Total number of examined seeds}} \times 100$$

STATISTICAL ANALYSIS

The data obtained from different experiments were analysed by the 'F' test of significance following the methods described by Panse and Sukhatme (1978). Wherever necessary, the per cent values were transformed to angular (Arc-sine) values before analysis. The Critical Differences (CD) was calculated at 5 per cent probability level. The data were tested for statistical significance. If the F test is non-significant it was indicated by the letters NS.

RESULT AND DISCUSSION

Seed storage is an important division of seed industry. In storage, vigour and viability of the seeds are maintained by many physic-chemical factors like initial seed quality, physical and chemical composition of seed, moisture content of seed, temperature, storage structure, gaseous exchange and packaging materials. Seed is hygroscopic in nature, storage environment act as a main role on the variation in moisture content {(Padma and Muralimohan Reddy (2001); McDonald (2004); Lehner *et al.* (2008)}. Seed is a biotic unit and the seed cells are made up of lipoprotein layers, they gain moisture during storage then fasten the lipid per-oxidation activity that leads to deterioration and at last death of the seed (Agarwal and Dadlani, 1995). In the current study, the seeds were treated with botanicals and chemical compounds before storage and packed in two containers like cloth bag and super grain bag evaluated for their suitability.

Seed physical characters during storage

Seed quality during storage can be governed by crucial factors such as the moisture content of the seed, storage conditions and packing materials. When seeds have been dried to a moisture level that is in equilibrium with 5–20°C

and 10–25% relative humidity, seed longevity during storage will be maximised (FAO, 2013). In this study, moisture content increased in stored seeds especially in cloth bag (8.3%) than super grain bag (7.6%) at the end of 8 month of storage period. Initially, the moisture content was 7.3 %. Because cloth bag was moisture pervious container and it permits the exchange of moisture in seed with environment. Minimum variation of moisture content was observed in super grain bag stored seeds, it's due to its impervious in nature and offered protection to seeds. Rise in seed moisture was due to the hygroscopic nature of seed (Harrington, 1972; Roberts, 1989). Minimum absorption of moisture was taken place in super grain bag after 8 months in maize seeds and also registered the lowest oxygen content opined by Anuradha Kumari *et al.* (2017). This was supported with Pundlik (2015) in paddy; Umesha *et al.* (2017) and Beedi *et al.* (2018) in chickpea.

Seed physiological characters during storage

Germination capacity is the basic requirement for seeds. Initially, 100 % of germination was obtained and it was declined to 89% irrespective of seed treatments and containers. The observation of other parameters *viz.*, root length, shoot length, dry matter production and vigour index also declined with increase of storage period. At the end of storage period, seeds packed in super grain bag had the highest germination percentage (91 %) compared to cloth bag (86 %) (**Plate.1**) (**Table 1**). On the other hand, the seeds in super grain bag registered the minimum reduction in all vigour parameters such as root length (18.0cm), shoot length (8.76 cm), dry matter production (0.161 g seedling⁻¹⁰) and vigour index I (2436) & II (14.7) (**Table 2&3**) while in cloth bag stored seeds recorded drastic reduction in vigour parameters. Seeds stored in Triple layer plastic bags showed higher germination percentage and other physiological characters because it prevented major damage caused by bruchids (*Callosobruchus maculatus* F.) in cowpea seeds, while seeds stored in gunny bags suffered severe losses (Vales *et al.*, 2014). Seedling vigour was higher in super grain stored seeds is due to the lowest seed damage (Kalsa *et al.*, 2019).

Table 1: Effect of seed treatment, storage containers and period of storage on germination (%) of horse gram

Treatment (T)	Containers (C) and Period of storage (P)												Grand Mean
	Cloth bag (C ₁)						Super grain bag (C ₂)						
	P ₀	P ₂	P ₄	P ₆	P ₈	Mean	P ₀	P ₂	P ₄	P ₆	P ₈	Mean	
T₀	100 (89.72)	93 (74.66)	90 (71.56)	87 (68.86)	84 (66.42)	91 (72.54)	100 (89.72)	97 (80.03)	94 (75.82)	91 (72.54)	89 (70.63)	94 (75.82)	93 (74.66)
T₁	100 (89.72)	98 (81.87)	95 (77.08)	91 (72.54)	88 (69.73)	94 (75.82)	100 (89.72)	100 (89.72)	98 (81.87)	96 (78.46)	94 (75.82)	98 (81.87)	96 (78.46)
T₂	100 (89.72)	94 (75.82)	91 (72.54)	89 (70.63)	85 (67.21)	92 (73.57)	100 (89.72)	98 (81.87)	95 (77.08)	93 (74.66)	90 (71.56)	95 (77.08)	94 (75.82)
T₃	100 (89.72)	96 (78.46)	93 (74.66)	91 (72.54)	87 (68.86)	93 (74.66)	100 (89.72)	100 (89.72)	97 (80.03)	94 (75.82)	92 (73.57)	97 (80.03)	95 (77.08)
T₄	100 (89.72)	95 (77.08)	92 (73.57)	90 (71.56)	86 (68.03)	93 (74.66)	100 (89.72)	99 (84.26)	96 (78.46)	93 (74.66)	91 (72.54)	96 (78.46)	94 (75.82)
Mean	100 (89.72)	97 (80.03)	92 (73.57)	89 (70.63)	86 (68.03)	93 (74.66)	100 (89.72)	99 (84.26)	96 (78.46)	93 (74.66)	91 (72.54)	96 (78.46)	94 (75.82)

	T	P	C	TXP	PXC	TXC	TXPXC
S. Ed	0.26	0.25	0.16	0.57	0.36	0.35	0.80
CD (P=0.05)	0.51	0.50	0.32	1.13	0.71	NS	NS

(Values in parentheses indicate arcsine transformed values);

C- Containers; P- Storage period in months; T- Treatments

T₀- Control T₁- Malathion 5g/kg T₂-Pungam leaf powder 5g/kg

T₃- Neem oil 5ml/kg T₄-Neem seed kernel powder 5g/kg

Table 2: Effect of seed treatment, storage containers and period of storage on vigour index I of horse gram

Treatment (T)	Containers (C) and Period of storage (P)												Grand Mean
	Cloth bag (C ₁)						Super grain bag (C ₂)						
	P ₀	P ₂	P ₄	P ₆	P ₈	Mean	P ₀	P ₂	P ₄	P ₆	P ₈	Mean	
T ₀	2859	2504	2383	2272	2117	2427	2859	2652	2531	2385	2326	2551	2489
T ₁	2859	2773	2654	2507	2406	2640	2859	2847	2752	2671	2551	2736	2688
T ₂	2859	2583	2468	2371	2220	2500	2859	2710	2590	2484	2389	2606	2553
T ₃	2859	2675	2565	2470	2324	2579	2859	2794	2691	2568	2478	2678	2628
T ₄	2859	2611	2500	2400	2258	2526	2859	2752	2627	2504	2435	2635	2581
Mean	2859	2629	2514	2404	2265	2534	2859	2751	2638	2522	2436	2641	2588

	T	P	C	TXP	PXC	TXC	TXPXC
S. Ed	18	18	11	40	25	25	57
CD (P=0.05)	35	35	22	79	50	NS	NS

C- Containers; P- Storage period in months; T- Treatments

T₀- Control T₁- Malathion @ 5g/kg T₂-Pungam leaf powder @ 5g/kg

T₃- Neem oil @ 5ml/kg T₄- Neem seed kernel powder @ 5g/kg

Table 3: Effect of seed treatment, storage containers and period of storage on vigour index II of horse gram

Treatment (T)	Containers (C) and Period of storage (P)												Grand Mean
	Cloth bag (C ₁)						Super grain bag (C ₂)						
	P ₀	P ₂	P ₄	P ₆	P ₈	Mean	P ₀	P ₂	P ₄	P ₆	P ₈	Mean	
T ₀	17.2	15.1	14.3	13.7	12.7	14.6	17.2	16.0	15.2	14.4	14.0	15.3	15.0
T ₁	17.2	16.7	16.0	15.1	14.5	15.9	17.2	17.1	16.6	16.1	15.4	16.5	16.2
T ₂	17.2	15.5	14.9	14.3	13.4	15.0	17.2	16.3	15.6	14.9	14.4	15.7	15.4
T ₃	17.2	16.1	15.4	14.9	14.0	15.5	17.2	16.8	16.2	15.4	14.9	16.1	15.8
T ₄	17.2	15.7	15.0	14.4	13.6	15.2	17.2	16.6	15.8	15.1	14.7	15.9	15.5
Mean	17.2	15.8	15.1	14.5	13.6	15.2	17.2	16.6	15.9	15.2	14.7	15.9	15.6

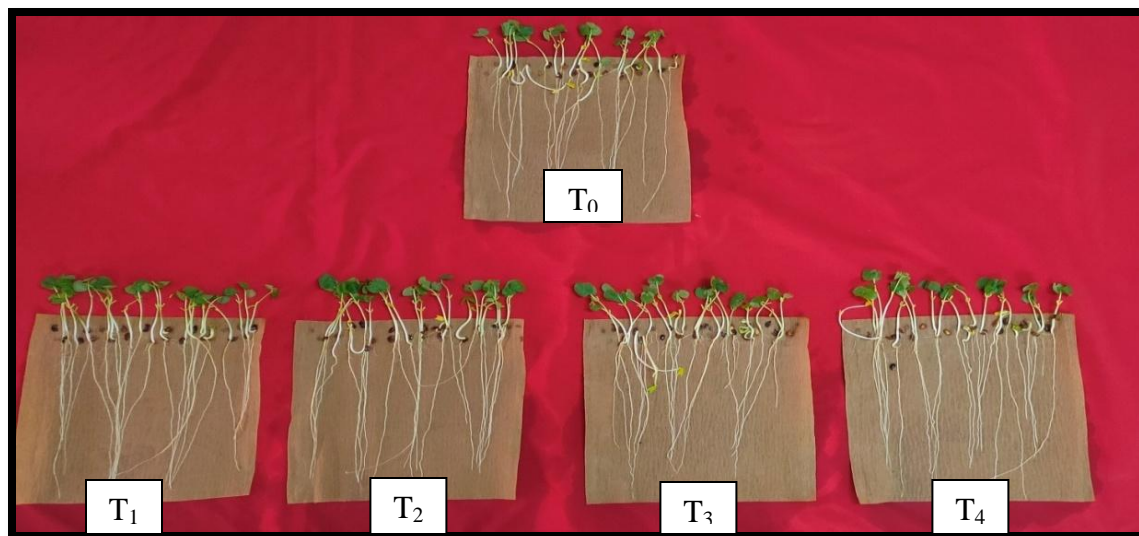
	T	P	C	TXP	PXC	TXC	TXPXC
S. Ed	0.1	0.1	0.03	0.1	0.1	0.1	0.2
CD (P=0.05)	0.1	0.1	0.1	0.2	0.2	NS	NS

C- Containers; P- Storage period in months; T- Treatments

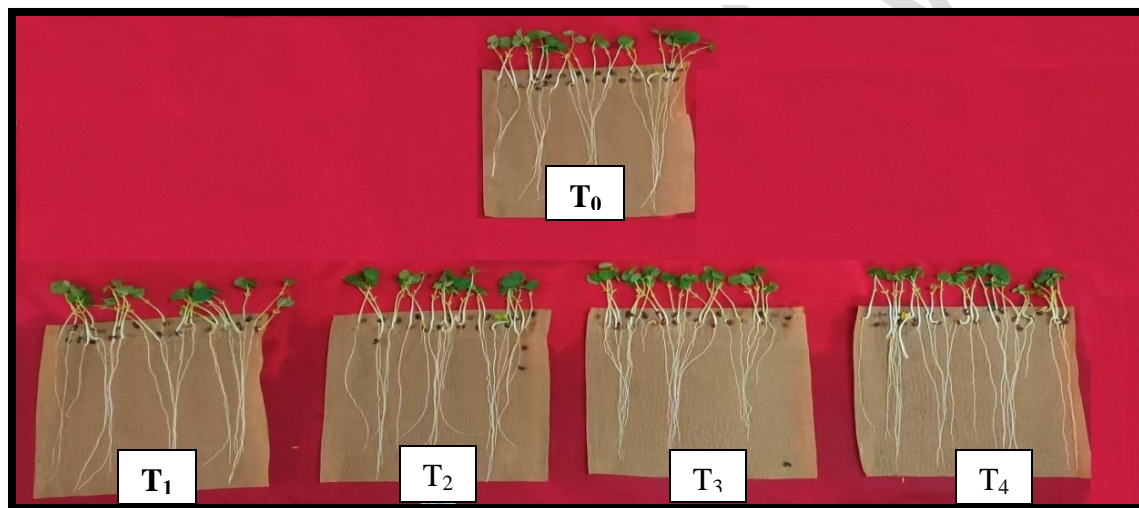
T₀- Control T₁- Malathion @ 5g/kg T₂-Pungam leaf powder @ 5g/kg

T₃- Neem oil @ 5ml/kg T₄-Neem seed kernel powder @ 5g/kg

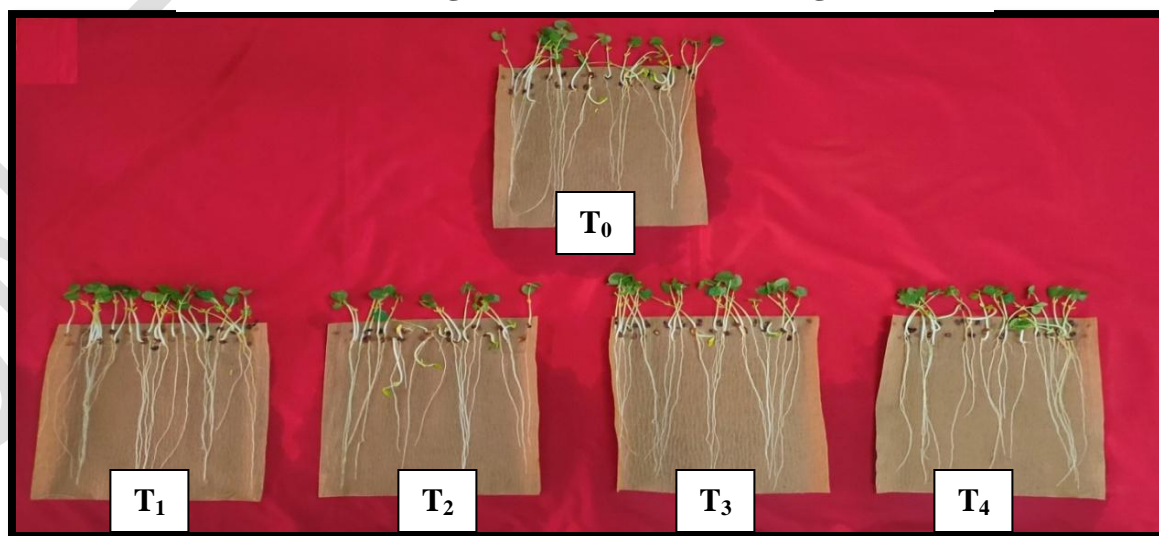
Plate 1: Effect of seed treatments and storage containers after 8 months of storage on horsegram



INITIAL



Cloth bag – After 8 months of storage



Super grain bag – After 8 months of storage

T₀-Control

T₁-Malathion 5g/kg

T₂-Pungam leaf powder 5g/kg

T₃-Neem oil 5ml/kg

T₄-Neem seed kernel powder 5g/kg

Important step in post harvest sequence of seed production programme is pre storage seed treatments (Gregg, 1967). Vigour and viability decreased during storage by many biotic factors like microflora and storage pests. So chemicals and botanicals were used to reduce the qualitative and quantitative losses and also it maintained the quality of seed for longer period. Among the seed treatments, Malathion treated seeds had higher germination (96%) than control (93%) after the storage of 8 months (Table 1). Similar results were reported by Bahukhandi *et al.* (2017) in berseem and Jagatap *et al.* (2014) in urdbean. Malathion dusted seeds with higher seed quality parameters than control was registered by Malarkodi and Srimathi (2001) in maize and Srimathi *et al.* (2001) in pearl millet.

The other physiological parameters like shoot length (9.42 cm), root length (18.66 cm), DMP (0.169 g seedling⁻¹) and vigour index I (2736) & II (16.5) (Table 2&3) were higher in seeds treated with malathion 5 g/kg and packed in super grain bag than control. Similar results were registered in cowpea (Lamani and Deshpande, 2016) and Sunhemp (Thimmanna *et al.*, 2014). Malathion treated seeds were deteriorated slowly due to the phosphate analogue addition to insecticidal property which favours the insect control, reduce deterioration and minimize the role of biotic factors was reported by Eevera (2000) in blackgram. Similar result was supported by Malarkodi (2003) in green gram.

Seed biochemical characters during storage

The seeds treated with malathion @ 5g/kg and packed in super grain bag registered the lowest electrical conductivity (0.121 dSm⁻¹) (Fig.3) compared to other treatments and control. This might be due to reduced seed permeability thus resulting lower electrical conductivity of leachates. Guha *et al.*, (2012) reported that okra seeds treated with red chilli powder and aspirin show extended protection against cell membrane and repair mechanisms during seed storage.

The protein content (19.21%) (Fig.4) and the activity of enzymes like Dehydrogenase (0.521) (Fig.2) and catalase (0.213 units g⁻¹) (Fig.1) were higher in malathion treated seeds which packed in super grain bag at the end of 8 months of storage period was registered as an added seed quality which influences the seeds storability in storage. Menaka (2000) reported activities of enzyme are answerable for respiration of seed reduced by age of seed with

additive response with the factors accountable for deterioration. Thimmanna *et al.* (2014) reported that dehydrogenase activity was higher in malathion treated seeds in sunhemp.

Seeds in cloth bags were highly damaged by bruchids and recorded the highest seed infestation (1.92%), compared to super grain bags (0.61%) at the end of 8 month of storage, whereas control bags recorded (2.27%). In super grain bags, the presence of minimum amount of oxygen was consumed by the respiration process of insects and microbes, which resulted in a carbon dioxide-rich atmosphere that reduced the insect infestation. Parallel results were investigated by Baldaniya *et al.* (2013); De Groote *et al.* (2013); Bakhtavar *et al.* (2019) and Covelet *et al.*, (2020).

CONCLUSION

Thus, the study revealed that among the seed treatments, malathion 5 g/kg kept the seeds completely free from insect infestation due to its toxic content when insects come into contact via skin, ingestion, or inhalation exposure, whereas it was not the case with other botanical seed treatments. Among the packing materials, seed stored in a super-grain bag has superior quality compared to a cloth bag because of its moisture-pervious nature. Because of this, there have been detrimental changes in seeds, such as cellular damage, delayed seedling emergence, and ultimate loss of viability. Therefore, seeds treated with malathion at 5 g/kg and stored in a supergrain bag are suitable to maintain the viability of seeds during storage in horse gram.

Effect of seed treatment and packaging material on biochemical properties of horsegram

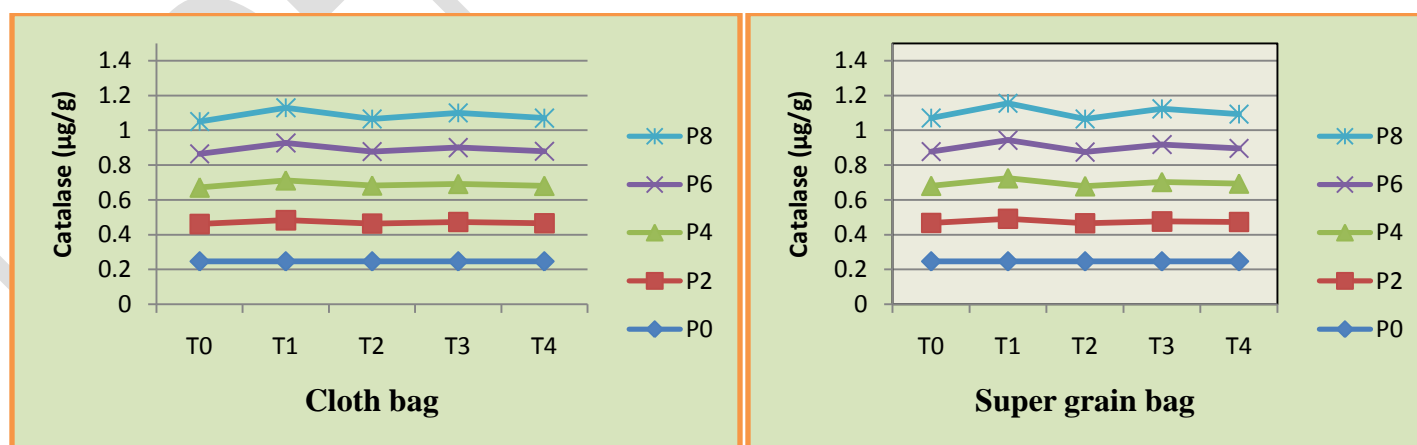


Fig. 1: Catalase activity (µg/g)

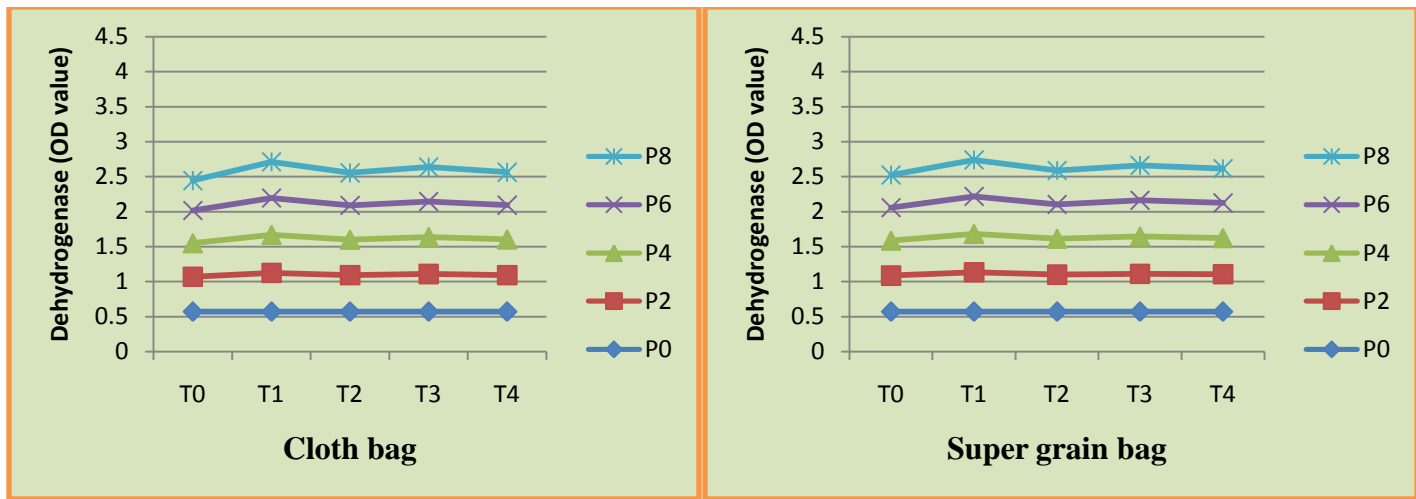


Fig. 2: Dehydrogenase activity (OD value)

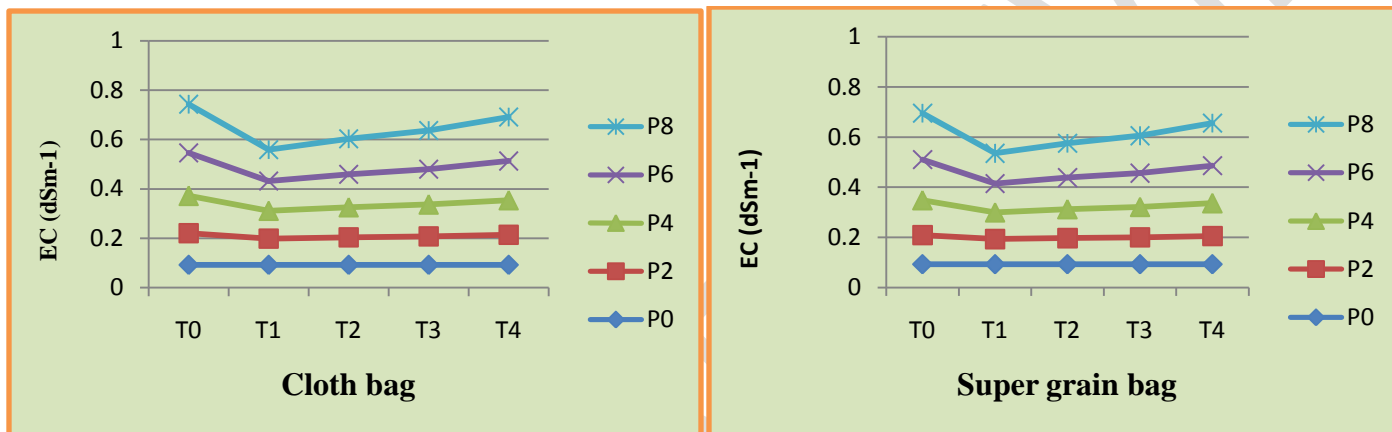


Fig. 3: Electrical conductivity(dSm⁻¹)

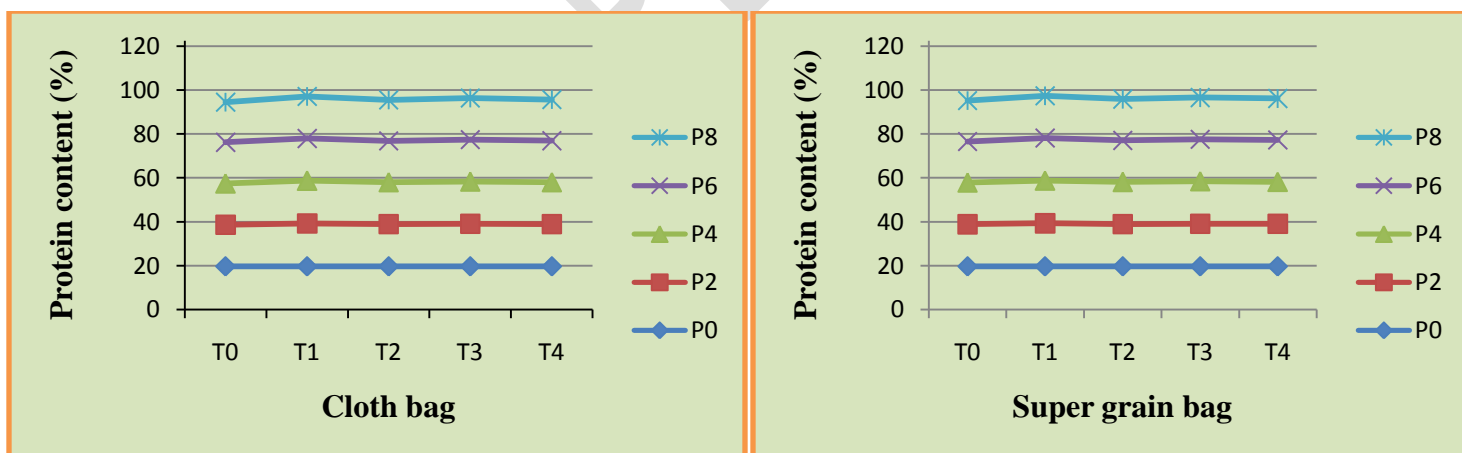


Fig. 4: Protein content (%)

T₀- Control T₁- Malathion @ 5g/kg T₂- Pungam leaf powder @ 5g/kg

T₃- Neem oil @ 5ml/kg T₄-Neem seed kernel powder @ 5g/kg

REFERENCE

- Abdul- Baki, A. A., & Anderson, J. D. (1973). Vigor determination in soybean seed by multiple criteria 1. *Crop science*, 13(6), 630-633.
- Abreu, L. A. D. S., Carvalho, M. L. M. D., Pinto, C. A. G., Kataoka, V. Y., & Silva, T. T. D. A. (2013). Deterioration of sunflower seeds during storage. *Journal of seed Science*, 35, 240-247.
- Agrawal, P. K., & Dadlani, M. (1987). *Techniques in seed science and technology* (No. 631.521 A2).
- Ali-Khan, S. T., & Youngs, C. G. (1973). Variation in protein content of field peas. *Canadian Journal of Plant Science*, 53(1), 37-41.
- Bahukhandi, D., Manjunatha, N., Vijay, D., & Singh, H. V. (2017). Effect of seed treatments and storage containers on seed quality of berseem (*Trifoliumalexandrinum* L.). *Range Management and Agroforestry*, 38(2), 227-233.
- Bakhtavar, M. A., Afzal, I., & Basra, S. M. A. (2019). Moisture adsorption isotherms and quality of seeds stored in conventional packaging materials and hermetic Super Bag. *PLoS One*, 14(2), e0207569.
- Baldaniyaet al.(2013). "Effect of Storage Containers and Durations on Enzymatic Activity of Onion Seed Under Ambient and Cold Temperature Condition."
- Beedi, S., Macha, S. I., Gowda, B., Savitha, A. S., &Kurnallikar, V. (2018). Effect of seed priming on germination percentage, shoot length, root length, seedling vigour index, moisture content and electrical conductivity in storage of kabuli chickpea cv., MNK (*Cicer arietinum* L.). *Journal of Pharmacognosy and Phytochemistry*, 7(1), 2005-2010.
- Covele, G., Gulube, A., Tivana, L., Ribeiro-Barros, A. I., Carvalho, M. O., Ndayiragije, A., &Nguenha, R. (2020). Effectiveness of hermetic containers in controlling paddy rice (*Oryza sativa* L.) storage insect pests. *Journal of Stored Products Research*, 89, 101710.
- De Groote, H., Kimenju, S. C., Likhayo, P., Kanampiu, F., Tefera, T., & Hellin, J. (2013). Effectiveness of hermetic systems in controlling maize storage pests in Kenya. *Journal of stored products research*, 53, 27-36.

Ferreira, T. F., Oliveira, J. A., Carvalho, R. A. D., Resende, L. S., Lopes, C. G. M., & Ferreira, V. D. F. (2016). Quality of soybean seeds treated with fungicides and insecticides before and after storage. *Journal of Seed Science*, 38, 278-286.

Food and Agriculture Organization of the United Nations. (2013). *Genebank Standards: For Plant Genetic Resources for Food and Agriculture*. Food and Agriculture Organization of the United Nations.

Gregg, Bill. 1967. "Quality Control in Processing Foundation Seed." *Mississippi Agricultural and Forestry Experiment Station*.

Guha, P., Biswas, J., De, B. K., & Mandal, A. K. (2012). Post-harvest dry and wet physiological seed treatments for improved storability and field performance of okra (*Abelmoschus esculentus* L.). *Indian Journal of Agricultural Research*, 46(1).

Harrington, J. F., & Kozlowski, T. T. (1972). Seed storage and longevity. *Seed biology*, 3, 145-245.

Indiastat.com. <https://www.indiastat.com/table/agriculture-data/2/kulthi-horse-gram/19568/1347635/data.aspx>

ISTA. 2013. *International rules for seed testing*. Bassersdorf (Switzerland): International Seed Testing Association.

Jagatap, S. J., Harer, P. N., Nagawade, D. R., & Tagad, L. N. (2014). Effect of botanical extract treatments on seed quality of urdbean (*Vigna mungo* L.) during post-harvest storage. *SKUAST Journal of Research*, 16(2), 82-92.

Kalsa, K. K., Subramanyam, B., Demissie, G., Mahroof, R., Worku, A., & Gabbiye, N. (2019). Evaluation of postharvest preservation strategies for stored wheat seed in Ethiopia. *Journal of Stored Products Research*, 81, 53-61.

Kittock, D. L., & Law, A. G. (1968). Relationship of seedling vigor to respiration and tetrazolium chloride reduction by germinating wheat seeds. *Agronomy Journal*, 60(3), 286-288.

Kumar, S., Gowda, B., & Shekhar, S. P. (2008). Influence of Storage Containers and Seed Pelleting on Seed Quality in Brinjal (*Solanum melongena* L.) during Storage. *Journal of Horticultural Sciences*, 3(2), 146-149.

Kumari, A., Kumar, V., Amitabh, A., Kumar, A., Kumar, M., & Kashyap, V. (2017). Qualitative loss of maize under different bag storage modes. *International Journal of Current Microbiology and Applied Sciences*, 6(12), 177-183.

Lamani, Koteshi, and VK Deshpande. (2016). "Effect of Botanical Seed Treatment on Storability of Cowpea (*Vigna unguiculata*)." *Advances in Life Sciences* 5 (2):539-544.

Lehner, A., Mamadou, N., Poels, P., Come, D., Bailly, C., & Corbineau, F. (2008). Changes in soluble carbohydrates, lipid peroxidation and antioxidant enzyme activities in the embryo during ageing in wheat grains. *Journal of Cereal Science*, 47(3), 555-565.

Luck, H. (1974). Estimation of catalase, methods in enzymatic analysis. *Bergmeyer, HU, & Gawhn, K.(Eds.)*, 885-894.

Malarkodi, K., & Srimathi, P. (2001). Effect of Insecticide Treatment on Maintenance of Seed Quality in Maize cv. Co 1. *Seed Research-New Delhi-*, 29(2), 197-201.

McDonald, M. B. (2004). Orthodox seed deterioration and its repair. *Handbook of Seed Physiology: Applications to Agriculture, Benech-Arnold, RL and RA Sanchez (Eds.)*. Food Products Press, New York, 273-304.

Menaka, C. (2000). Seed technological studies in amaranthus (*A. tricolor*) cv. CO 5. *Unpublished M. Sc (Ag) Thesis*. Tamil Nadu Agricultural University, Coimbatore.

Padma, V., & Muralimohan Reddy, B. (2001). Seed invigoration for extending storability of soybean seed. *Journal of Research Acharya NG Range Agricultural University*, 29(4), 1-5.

Panse, VC, and PV Sukhatme. 1978. "Statistical methods for Agricultural workers. III Rev." *Ed. ICAR, New Delhi*.

Presley, J. T. (1958). Relation of protoplast permeability to cotton seed viability and predisposition to seedling disease. *Plant Disease Reporter*, 42(7), 852.

Pundlik, Divekar Santosh. (2015). "Studies on Flexible Hermetic Storage System for Paddy." *Ph.D Thesis*. Division Of Agricultural Engineering Indian Agricultural Research Inst. New Delhi.

Roberts, E. H., & Ellis, R. H. (1989). Water and seed survival. *Annals of botany*, 63(1), 39-39.

Srimathi, P., Malarkodi, K., & Sastri, G. (2001). Influence of fungicides and insecticides on storability of pearl millet seeds. *Madras Agricultural Journal*, 88(jan-mar), 1.

Thimmanna, D., Channakeshava, B. C., Sharanappa, J., & Nataraja, M. (2014). Effect of packaging materials and seed treatment chemicals on seed quality of sunnhemp during storage. *International Journal of Tropical Agriculture*, 32(3/4), 513-523.

Umesha, U., Channakeshava, B. C., Bhanuprakash, K., Nuthan, D., Siddaraju, R., & Lakshmi, J. (2017). Influence of seed treatment and packaging materials on seed longevity of cluster bean [*Cyamopsis tetragonoloba* (L.) Taub.]. *Journal of Applied and Natural Science*, 9(1), 482-491.

Vales, M. I., Rao, G. R., Sudini, H., Patil, S. B., & Murdock, L. L. (2014). Effective and economic storage of pigeonpea seed in triple layer plastic bags. *Journal of stored products research*, 58, 29-38.